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COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 585 APRIL 1940

DIVISION OF VETERINARY SCIENCE

IN COOPERATION WITH THE BUREAU OF ANIMAL INDUSTRY, PATHOLOGICAL DIVISION, UNITED STATES DEPARTMENT OF AGRICULTURE

Poisoning in Sheep and Goats by Sacahuiste (*Nolina Texana*) Buds and Blooms

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
T. O. WALTON, President

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The buds and blooms of sacahuiste *(Nolina texana)* are poisonous for sheep, goats, and cattle, while no untoward results have been noted when cattle graze upon the leaves of the plant. Sheep and goats have not been observed to graze on the rather coarse leaves of the plant but are very fond of the tender buds and blooms. When these are consumed by sheep and goats in amounts greater than one per cent of their body weight the animals become sick and usually die. If only dry feed is available at this time the animals will be very much depressed and icteric due to a marked degeneration of the liver cells and by obstruction of the bile ducts. If some green feed is consumed at the same time then in addition to the symptoms and lesions just noted, the animals will become photosensitive and if they are now exposed to the sun will develop itching of the skin and a marked swelling of the skin and subcutaneous tissue of the head, including the ears. Losses from this source may be prevented by removing the animals from the infested pasture during the blooming season or by concentrating the animals on a smaller area in the pasture or removing them to less heavily infested areas so that they will not be able to consume a toxic dose during a day's grazing.

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POISONING IN SHEEP AND GOATS BY SACAHUISTE *(NOLINA TEXANA)* BUDS AND BLOOMS

By

Frank P. Mathews, Veterinarian, in Charge Loco Weed Laboratory, Alpine

IN COOPERATION WITH THE BUREAU OF ANIMAL INDUSTRY, PATHOLOGICAL DIVISION, UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

Although sacahuiste is a relatively common plant on the ranges of western Texas, the toxicity of the buds and blooms is a controversial subject among the ranchers of this region. Due to the fact that the blooming season occurs at a time when other succulent feed is scarce many ranchers maintain that they are good feed and look forward to this season. On the other hand, the rancher who appreciates the potential danger from this part of the plant approaches the blooming season with considerable apprehension. Given enough time and suitable conditions, the rancher who considers this part of the plant suitable forage will eventually learn the fallacy of such a belief. This statement applies only to the buds, blooms, and ripe fruit; the leaves of the plant are another story and one upon which more will be said later in this publication.

Sacahuiste poisoning is generally referred to as "swellhead" or "fevered." The former term is applied when photosensitization is a prominent part of the clinical picture, the latter when this lesion is absent and in which case icterus is the only outstanding symptom. Sheep, goats, and cattle are affected. The disease occurs during the blooming season of the plant, which, in the vicinity of Alpine, is shortly after the first of April, but may be earlier or later depending on variations in seasonal conditions; at lower altitudes the season is somewhat earlier. The average blooming season generally covers a period of about three weeks, although this may be shortened or lengthened by late freezes which frequently occur in the Trans-Pecos region of Texas. A late freeze at the beginning of the blooming season may be followed by a blooming season of about the normal length; a freeze during the middle of the blooming season is generally followed by the appearance of but few blooms.

The morbidity of the animals varies from 1 to as high as 20 per cent, depending upon the number of blooms. A heavy crop of blooms is associated with a corresponding morbidity, and a light crop, with little or no loss. Fortunately a heavy crop of blooms does not occur oftener than about once every five or six years. If no losses occur it is obvious that none of the animals obtained sufficient material to produce toxic effects, a result that evidently accounts for the viewpoint of some ranchers.

The mortality is about the same as the morbidity since very few animals recover if they have eaten sufficient of the toxic material to produce

symptoms of the disease. In cattle the loss is seldom as serious as it is in sheep and goats. However, in a herd of 100 head of cattle a loss of 20 head was observed and the animals in this case were removed from access to the buds and blooms before the season was over. In the presence of an abundant crop of blooms it is a common sight to see a ring of either sheep or goats around a bunch of sacahuiste with their heads buried among the leaves seeking the succulent feed. This picture is always associated with a heavy loss.

The disease is characterized by icterus, liver and kidney lesions and generally an edematous swelling of the face and ears, although the latter manifestation is not a constant part of the clinical picture. The symptoms and pathology are similar to that produced by the grazing of the leaves of lechuguilla as well as several other poisonous plants, of which part of the toxicology is a photosensitization. Tunnicliff (1) produced a swelling of the head of one lamb by feeding the fruit, both ripe and immature, of sacahuiste, which is evidently the only published report on the toxic nature of this plant. A review of the literature on the photodynamic diseases of the lower animals was presented by the writer in two recent publications and is omitted at this time (2, 3).

BOTANICAL DESCRIPTION OF *NOLINA TEXANA**

Nolina texana S. Watson (sacahuiste), of the lily family is a perennial plant with a thick, short caudex (woody base) usually 15 cm. tall or less and mostly underground, which in well-developed plants is usually as much as 30 cm. broad or more at or somewhat above the surface of the ground.

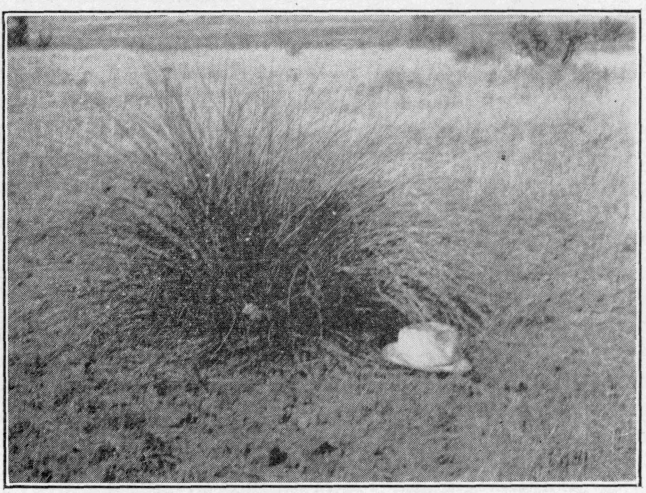

Fig. 1. A bunch of sacahuiste showing 1 bloom.

(*Botanical description by V. L. Cory, Range Botanist, Texas Agricultural Experiment Station, Substation No. 14, Sonora, Texas.)

The caudex has many short branches, each bearing a cluster, as many as 20 or more, of long, narrowly linear leaves. Under favorable conditions a plant will bear several to many, up to 20 or more, stout, nearly naked flowering stems. The leaves are dilated at the base, 60-160 cm. long, 2-5 mm. broad, concavo-convex below, with a prominent ridge on the concave upper surface, becoming sharply 3-angled towards the apex, minutely roughish on the margins, and are spreading or drooping to cover the ground. In the older foliage the apical portion, from a small fraction up to as much as a third or half the length of the leaf, usually is dead. The flowering stems are up to 60 cm. tall, towards the base as much as 1 cm. broad, and bear a compound, or branched, racemose, many-flowered panicle, the main branches of which are subtended by long-attenuate leaf-like bracts with dilated papery bases, and with the tips of the lower bracts exceeding the inflorescence. The main panicle branches are as much as 10-15 cm. long, each usually with 6 or more rather weak, strongly ascending branchlets, each of which bear from a few up to 10 or more pedicels which are 4-6 mm. long, articulated well below the base, and each bearing a solitary, small, polygamo-dioecious flower having small white segments, which are withering-persistent. The fruit is dry, deeply 3-lobed, appearing almost as 3 separate globose carpels. The carpels are thin and open tardily and irregularly after maturity, with usually only one seed developing in a carpel. The seed is light-colored, nearly smooth, somewhat depressed, 4 mm. high and 5-6 mm. broad.

The plant has not been reported as growing elsewhere than in Texas. The early collections of the plant by botanists were mostly from the eastern portion of its range, including Hamilton, Travis, Blanco, Comal, Gillespie and Kerr counties. From this portion of its former occurrence the plant

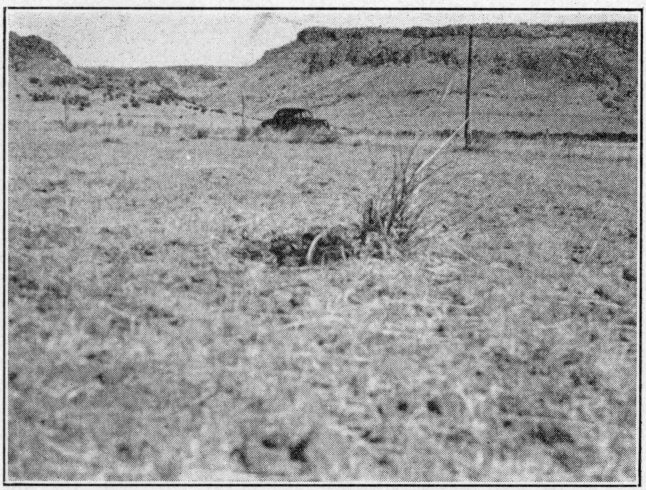

Fig. 2. A bunch of sacahuiste almost killed by cattle grazing.

at the present time has disappeared for the most part, and its extermination on the range, under conditions of continuous grazing, is proceeding steadily on westward. Inasmuch as the young plants are more palatable than the older ones under ranching conditions the attempted reproduction of the species is thwarted, hence, in the course of time, except where protected, it will cease to be a part of the range vegetation. At the present time the plant is most abundant on the rolling hills or foothills of the Trans-Pecos area of Texas. On the Edwards Plateau, towards the northeastern limit of its occurrence, sacahuiste blooms in the winter, usually from January on into March, the time being influenced by moisture conditions; in dry years it does not bloom at all. In the higher elevations of the Trans-Pecos area blooming is delayed until after the first of April.

NATURAL OCCURRENCE OF THE DISEASE

Symptoms

Manifestations of the disease are much the same in cattle, sheep and goats. Loss of appetite appears to be the first evidence of intoxication, followed within a day or two by a generalized icterus, which is of an unusual intense yellow. The sick animals remain around the watering places, make no attempt to follow the flock and are constantly seeking shade. There is a gradual and progressive debilitation and the majority of the cases do not live more than a week after the first symptoms appear, although life may be prolonged as much as two weeks. Recovery is the exception rather than the rule. Watering of the eyes which at first is serous later becomes muco-purulent, adheres to the internal canthus of the eye and to the wool or hair for a variable distance along the face. There is a tenacious, yellow nasal discharge. A purplish band about one-half inch in width is generally found around the top of the hoof below the coronary band. Judging from observations on experimental animals this band is probably a photodynamic response of unpigmented hoofs. The urine is generally of a darker yellow color than normal, but at times it has a port wine appearance. In such cases the staining of the hair or wool suggests bloody urine but there are no red blood corpuscles present. Otherwise, the nature of the pigment in the urine has not been determined. Pruritis, which is an outstanding symptom in some of the other photodynamic diseases is frequently observed, although it is not a constant symptom. This symptom is evidently one of the first reactions to sunlight exposure, decreasing with subsequent exposures until by the third day it is no longer present.

Pathology

Upon autopsy, in addition to the intense and generalized icterus, two lesions are constantly observed in all species of animals. The liver has a light yellowish-brown to greenish cast and when cut has a slightly greasy appearance. Pressure exerted along the edges of the cut surface results in the expulsion of numerous viscid green plugs from the severed

bile ducts. No particular change is noted in the gall bladder or the contents thereof. The kidneys are always swollen, sometimes to as much as twice their normal size, and are greenish-brown to greenish-black in color. Upon incision urine drips from the cut surface and many of the tubules are distended to the point that they can be distinguished with the unaided eye.

Evidence of a photodynamic reaction may or may not be present as this is not constant. Furthermore, in many cases the edematous infiltration of the corium and underlying connective tissue is soon absorbed. If the edematous infiltration is soon absorbed very little necrosis of the skin will result, thus leaving no evidence of the previous existence of the infiltration. On the other hand the edema may be sufficiently extensive

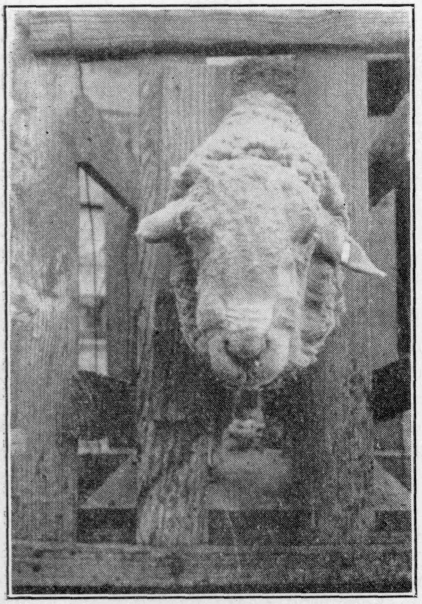

Fig. 3. Sheep 64 showing the characteristic swelling of the face and ears 24 hours after the first exposure to light.

to produce a rounded appearance of the face and the ears, which may be swollen as much as an inch in thickness, are drooped on account of the excess weight. In such cases rupture of the skin of the ears is rather common and a clear amber fluid drips from the rupture. If the life of such animal is prolonged for a sufficient time there is extensive necrosis of the skin, thick, rigid scab formation and in the event of ultimate recovery complete healing beneath the scab. During recovery, in the area here under discussion, such cases are frequently subject to screw worm infestations. In the cases of recovery which have come to the attention of the author, shedding of the wool has been a late sequel.

Microscopically the liver presents a uniform and pronounced albuminous degeneration with distortion of the normal cord-like arrangement of the

parenchymatous cells. Adjacent to the central veins the liver cells present a foam-like structure due to fatty changes. These changes become less noticeable as the periphery of the lobule is approached. Many of the bile ducts are plugged with casts consisting of a nucleus of cholesterol crystals surrounded by cellular detritus, similarly as is observed in lechuguilla poisoning. Numerous clefts resulting from the dissolving out of cholesterol during infiltration and staining furnish evidence of considerable deposition of this lipoid in the liver cells.

The kidneys show a pronounced albuminous degeneration and marked fatty changes of both the tubular and glomerular epithelium. Many of the tubules are filled with casts which may be hyaline and take a bright eosin stain or are composed of loosely arranged, amorphous material which takes very little stain. Above the casts the tubules are distended with urine with the distention in some tubules extending into Bowman's capsule. Bowman's capsule is frequently distended with casts similar to those found in the tubules. Much of the tubular epithelium has a greenish-brown appearance due to the deposits of bile salts within the epithelium.

The edematous reaction in the corium and underlying connective tissue is due to an injury to the endothelium of the capillaries and smaller veins. Both the nucleus and cytoplasm of the injured endothelium are edematous and stain faintly with their respective stains. This injury is accompanied by an escape of serum into the surrounding tissue and infiltration by various wandering cells. the predominant type being polymorphonuclear leucocytes. The presence of plasma cells is a conspicuous part of the histological picture, and the distribution of this type of cell, which in many instances is around an injured blood vessel, suggests that this cellular response is reparative in nature, with a function of preventing the escape of the serum to the surrounding tissue. Necrosis may be superficial or extend well into the corium, and is associated with a marked polymorphonuclear leucocytic infiltration along the margin of the necrosed areas.

EXPERIMENTAL PROCEDURE

The experimental animals consisted of 9 Angora goats, 18 white sheep, and 25 albino rats. The ages of the sheep and goats varied from about 8 months to several years. The most of the work was conducted during the blooming seasons of 1932, and 1936 to 1939 inclusive. Since, under range conditions, the fresh buds and blooms were evidently quite palatable it was assumed that they would be readily eaten under experimental conditions. In the first experiment, however, it was found that the greater part of the alfalfa hay which was generally fed had to be withheld in order to induce the animals to eat the desired amounts of sacahuiste buds. In following experiments weighed amounts of the plant were force fed, each daily dose being divided into two equal parts, one part being fed in the morning, the second in the afternoon. All animals were allowed cured alfalfa ad libitum, in addition some of the animals were fed two to three pounds of fresh green grass daily. Six of the animals were

maintained in a shed with an open southern exposure, thus being exposed to more or less direct sunlight for the duration of the experiment. The remainder were housed in a closed shed and not exposed to direct sunlight until the first appearance of icterus. Exposures were made twice daily for three consecutive days from 11:00 a. m. to 12 m. and from 1:00 p. m. to 2:00 p. m., provided the affected animals were able to tolerate the full hour in the afternoon. The rats were housed in a building and exposed at various intervals, the exposures generally being completed before 10:00 a. m., and a second exposure being made for such time as the animals were able to tolerate after 1:00 p. m.

Results of Experimental Feeding

The results of feeding the buds and blooms to sheep are summarized in Tables 1 and 2. In these tables the sheep which are shown to have become icteric but not photosensitive had been fed cured alfalfa in addition to the sacahuiste. The sheep which developed icterus and were photosensitive had been fed fresh green grass in addition to cured alfalfa, four

Table 1. The toxicity of buds, blooms and ripe fruit of sacahuiste for sheep. Alfalfa hay fed in addition to sacahuiste

Animal Number	Weight of animal	Feeding period	Total amount fed	Amount fed daily	Percent body weight fed daily	Results
	Lbs.	Days	Lbs.	Lbs.		
15	65	25	11.5	0.46	0.7	No ill effects
30	90	12	8.0	0.66	0.73	No ill effects
1A	100	12	9.6	0.8	0.8	No ill effects
13	65	28	18.0	0.65	1.0	No ill effects
56	70	11	7.7	0.7	1.0	No ill effects
14	60	28	18.0	0.65	1.08	No ill effects
30	65	6	4.2	0.7	1.08	No ill effects
3A	67	6	6.0	1.0	1.5	No ill effects
63	40	9	5.0*	0.55	1.3	Icteric 9th day; not photosensitive
71	90	12	12.0	1.0	1.1	Icteric 12th day; not photosensitive
56	70	11	11.0	1.0	1.28	Icteric 8th day; not photosensitive
70	70	12	12.0	1.0	1.4	Icteric 12th day; not photosensitive
12	60	13	12.2	0.93	1.5	Icteric 8th day; not photosensitive
68	75	7	10.0	1.4	1.8	Icteric 7th day; not photosensitive
37	80	5	11.25	2.25	2.8	Icteric 5th day; not photosensitive

*Fed ground ripe fruit.

of them having been fed rescue grass *(Bromus catharticus)*, the other two green Johnson grass *(Sorghum halepense)*. In addition to the grass they were allowed alfalfa hay ad libitum. From these tables it will be noticed that daily doses of buds and blooms ranging from 0.7 to 1.08 per cent of the body weight had no ill effects when fed in conjunction with cured alfalfa. As no ill effects were noted in the case of sheep 14, which received 28 doses of buds, each representing 1.08 per cent of the body weight it appears that there was no cumulative effect of the poison. With one exception (Sheep 3A, fed but 6 doses), doses of 1.1 per cent of the body weight eventually produced toxic effects. Therefore, in the presence of dry feed 1.1 per cent of the body weight is very close to the minimum toxic

Table 2. The toxicity of buds and blooms of sacahuiste for sheep. Alfalfa hay plus two to three pounds fresh green grass fed in addition to sacahuiste

Animal Number	Weight of animal	Feeding period	Total amount fed	Amount fed daily	Percent body weight fed daily	Results
	Lbs.	Days	Lbs.	Lbs.		
68	85	12	9.6	0.8	0.94	Icteric 12th day; photosensitive
2A	97	6	6.0	1.0	1.0	Icteric 6th day; photosensitive
72	57	6	4.2	0.7	1.2	Icteric 5th day; photosensitive
65	55	12	8.0	0.66	1.2	Icteric 8th day; photosensitive
73	90	5	11.25	2.25	2.5	Icteric 5th day; photosensitive
64	70	5	11.25	2.25	6.2	Icteric 5th day; photosensitive

Sheep 73 and 64 were fed dry blooms; weight of dry material being expressed as its original weight of green plant material.
Sheep 68, 2A, 72 and 65 were fed fresh green buds and blooms.

dose. Since 12 days were required to produce toxic effects at this level of feeding and but 5 days when the daily dose was increased to 2.2 per cent of the body weight it is probably safe to conclude that the larger the dose the quicker toxic effects will occur.

The addition of fresh green grass to the daily ration of sacahuiste produced two interesting results. First, less sacahuiste was required to produce icterus (sheep 68 and 2A); second, the six animals which were fed green grass all became photosensitive. This condition was not observed in the controls which received no green grass. The dried blooms were found to retain their toxicity for as long as eight months as sheep 73 and sheep 64 were fed the material after drying for this length of time. The ground ripe fruit of the plant was also found to be toxic. However, the toxic content of the fruit is evidently much less than that of the buds and blooms as, in the case of sheep 63, doses representing 1.3 per cent of the body weight were required to produce intoxication. Sheep 63 is one of the three animals which recovered, thus indicating a milder case.

Six goats were fed the same material as was employed in feeding of the sheep and the results of this experiment are summarized in Table 3. These animals were all fed dry alfalfa, none being fed green grass. As

Table 3. The toxicity of buds and blooms of sacahuiste for goats. Alfalfa hay fed in addition to sacahuiste

Animal Number	Weight of animal	Feeding period	Total amount fed	Amount fed daily	Percent body weight fed daily	Results
	Lbs.	Days	Lbs.	Lbs.		
30	125	27	21.6	0.8	0.64	Icteric 30th day; not photosensitive
10	105	27	21.6	0.8	0.76	Icteric 30th day; not photosensitive
3	80	16	15.0	0.93	1.16	Icteric 16th day; not photosensitive
18	115	26	38.0	1.4	1.2	Icteric 30th day; not photosensitive
7	95	13	18.0	1.4	1.4	Icteric 12th day; not photosensitive
46	50	12	8.4*	0.7	1.4	Icteric 11th day; not photosensitive

*Dry material expressed as green plant (66.6 per cent moisture).

is indicated in the table all the goats developed icterus but none became photosensitive. Since 27 doses, each representing 0.64 per cent of the body weight of goat 30, were sufficient to produce icterus and later a fatal termination, it is concluded that goats are more susceptible to the toxic principle than are sheep. As was the case with sheep when allowance is made for individual susceptibility, the larger the dose the quicker icterus was produced.

Intermittent Feeding

The effect of intermittent feeding was tested on three goats and the results are presented in Table 4. The animals in this experiment were all of the same age and weight and were fed the same amount of the

Table 4. Intermittent feeding of the dry buds and blooms of sacahuiste to goats. Alfalfa hay fed ad libitum

Date	Animal Number**			Date	Animal Number
	37	44	41		44—continued
	Grams fed				Grams fed
December, 1932				February, 1933	
12	100	100	100	12	150
13	100	100	100	13	150
16	100	100	100	14	150
17	100	100	100	15	150
19	100	100	100	16	150
24	100	100	100–icteric	17	150
				18	150
26	100	100	.....	19	150
				20	150
				21	150
January, 1933				22	150
3	.....	.....	Died		No ill effects
10	100	100			
11	100	100			
12	100	100			
13	100	100			
19	100	100			
20	125	125			
21	150	150			
23	150	150			
24*	150	150			
	No ill effects				

*Feeding of goat 37 discontinued on account of lack of sufficient blooms.
**Weight of goats, 55 pounds each. Per cent of body weight of dry plant fed on the basis of green plant as follows:

100 gm. = 1.2 %
125 gm. = 1.5 %
150 gm. = 1.81 %

plant. Between December 12 and December 20 each animal was fed five times, each feeding consisting of 100 grams of the dry blooms, equivalent to 0.66 pound of the green plant and 1.2 per cent of the body weight. The feedings were omitted from December 21 to 23, and on December 24 goat 41 was found to be icteric but was given one more feeding on that day. It died on January 3, 1933.

From December 24, 1932, to January 19, 1933, the other two goats received seven doses, each representing the same body weight as in previous feedings. On January 20 the amount was increased to 1.5 per cent

of the body weight and on January 21 to 24 they were fed 1.81 per cent of the body weight. By January 24 the supply of buds and blooms was not sufficient to continue the two animals for which reason the feeding of this plant material to goat 37 was discontinued. From February 12 to 22, inclusive, goat 44 was fed 1.81 per cent of the body weight daily, or a total of 11 feeds. The appetite remained good and no ill effects were noted. It is evident that there is considerable variation in the susceptibility of different animals of the same species; however, there is some question in the case of goat 44 as to whether or not the resistance encountered in this animal was entirely due to individual resistance or to a possible acquired resistance which was brought about by the earlier intermittent feeding of small doses. It hardly seems possible that this animal could have tolerated 11 consecutive doses, each representing 1.81 per cent of the body weight at the beginning of the experiment.

Symptoms and Pathology of Experimental Cases

From a study of the experimental cases there is little to be added to the discussion of symptoms which has been previously presented in this paper. Loss of appetite is unquestionably the first evidence of intoxication and appears from one to three days before recognizable icterus. The pruritis which is part of the photodynamic reaction is quite intense during the first sunlight exposure, especially of the ears and about the nostrils. The pruritis is less noticeable upon exposure the following day and by the third day light exposures caused little or no distress. In recently shorn sheep a peculiar crouching condition was manifested shortly after pruritis appeared. The affected animal would gradually flex the hock joint, thus lowering the hind quarters until extreme flexion was reached at the joint,

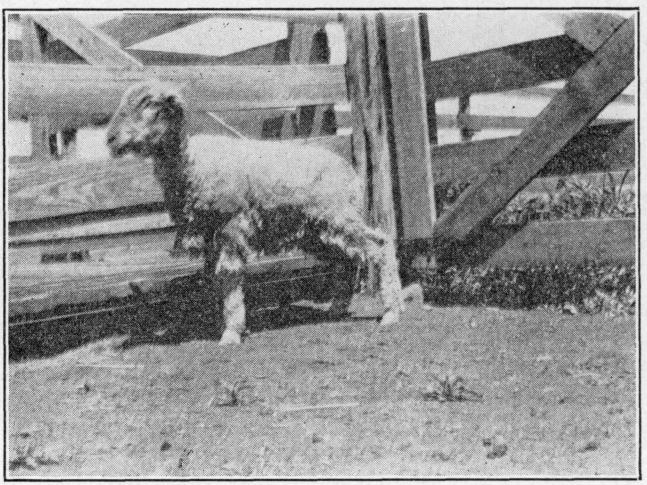

Fig. 4. Sheep 73 showing the peculiar crouching attitude assumed during the first exposure to light.

the hock would then be extended and the rear quarters elevated to their normal level. This lowering and raising of the hind quarters was continuous during light exposure and paralleled other evidence of photosensitization. Stamping of the feet was about as constant as rubbing of the ears and was started and discontinued about the same time, thus suggesting that this symptom as well as the purplish band which appeared at the top of the hoof was part of the photodynamic reaction.

Under the heading of pathology the results of blood studies of affected animals remains to be presented. The blood studies consisted of total and differential leucocytic counts, red blood corpuscles and non-protein nitrogen determinations. The figures obtained from the studies of two representative animals are presented in Table 5. The first studies were made on the

Table 5. Changes in the blood picture as observed in two goats after symptoms of sacahuiste poisoning appeared; normal also listed for comparison

Animal Number	Red Blood Corpuscles, Millions per cubic millimeter	Leucocytes, Thousands per cubic millimeter	Differential leucocyte count				Non-protein nitrogen mg. per 100 c.c.
			Poly. Per-cent	Lymph. Per-cent	Mono. Per-cent	Eosin. Per-cent	
1N*	22.0	10.0	29	66	3	2	36
41**	20.0	7.6	65	28	4	3	65
41***	8.0	19.0	88	9	3	0	144
3**	19.0	12.6	57	38	5	0	Not determined
3***	19.5	16.0	80	18	2	0	Not determined

*The approximate normal as determined on healthy goats in the region of Alpine, Texas.
**First determination at the time icterus was first detected.
***Second determination one week after icterus was first detected.

day icterus was first detected, the second one week later or as happened in both cases one day before death. The constant blood changes noted were an increase in the total number of leucocytes per cubic millimeter of blood and a corresponding increase in the percentage of polymorphonuclears. The non-protein nitrogen content of the blood was noticeably increased by the time icterus was detectable and reached very high levels shortly before death. In view of the kidney destruction the high non-protein nitrogen level is not surprising. There was generally a slight decrease in the total number of red blood corpuscles per cubic millimeter and in two cases there was an actual anemia such as is recorded in goat 41. For two days preceding death the urine of this animal was port wine in color and it was assumed that the color was due to hemoglobin, no red cells being present. Albuminuria is also a constant factor appearing about the same time as icterus.

The mortality rate was very high, for out of 19 animals in which icterus was produced only three recovered and one of these was sheep 63 which was fed the ripe fruit and from all indications was the mildest case produced. The figures on the mortality are slightly misleading as five of the

animals were killed for pathological studies. At the time of slaughter four of these were in such a condition that recovery was exceedingly doubtful. The fifth animal was killed at the height of the photodynamic reaction at which time no prognosis was possible; however, the other five animals in which photosensitization was produced died. Excluding the five animals upon which controversy can arise there was a recovery of three out of 14 animals, a somewhat higher percentage of recovery than is generally observed under range conditions.

TOXIC PRINCIPLE OF SACAHUISTE

Efforts to obtain hepato-nephro-toxin from the dried buds and blooms have thus far been unsuccessful. The ground material has been extracted with 70 and 96 per cent ethyl alcohol, water, and methyl alcohol. The feeding of the extracts to rats with the exception of the one obtained with 96 per cent ethyl alcohol, at the rate of 1 to 1.8 grams per day for as much as a week has produced no ill effects other than a constant diarrhea. The feeding of the dried 96 per cent ethyl alcohol extract at the rate of one gram per day for six consecutive days resulted in the death of rats, but it is probable that death in these cases was due to the persistent purgation rather than a specific hepato-nephro-toxin. The microscopic changes in these rats failed to indicate the presence of such a toxin. Fractional separation of the 96 per cent alcoholic extract resulted in no concentration of the toxic principle; ether extracts were non-toxic and all other efforts at concentration resulted in a non-toxic soluble fraction and an insoluble resinous fraction which could not be fed to rats by the use of the stomach tube.

Rats were fed various amounts of the 96 per cent ethyl alcohol extract for three days and exposed to direct sunlight. Fifteen rats thus treated were not rendered photosensitive. Emulsions of fresh green bermuda grass were mixed with the alcoholic extract and fed to eight additional rats. Upon exposure to sunlight these animals were found to be photosensitive. The photosensitization in these cases is evidently due to phylloerythrin, a matter which receives further consideration under the discussion. Six pounds of the dried blooms were extracted twice with 90 per cent ethyl alcohol, the alcohol evaporated off and the residue (145 grams) was fed to a 40-pound lamb in three equal doses. No ill effects were noted.

The Leaf of the Plant

No experimental evidence concerning the toxic or non-toxic properties of the leaf is available. This information was desired but sheep could not be induced to eat the leaf and due to its fibrous nature it could not be ground in an ordinary meat chopper, which is our method of preparing plant material for force feeding. Judging from field observations this part of the plant appears to be non-toxic for cattle. In a sacahuiste region during the winter months it is a common sight to see cattle with a bright green discoloration of the face and jaws extending up to about a

level of the eyes. This discoloration is acquired while grazing the leaves of the plant which are extensively grazed during the winter months, and over a period of years eventually tends to extermination of the plant. From these observations it is evident that the leaf is quite palatable to cattle during the winter months. No ill effects have been observed as a result of the grazing and in all probability some food value is derived therefrom. Sheep and goats rarely eat the leaves and when they do, it is to such a limited extent that no ill effects could result even if they were as toxic as the blooms or buds, which they are evidently not.

CONTROL

The control of this disease is a problem in ranch management and due to the short duration of the blooming season it may be accomplished without a great deal of expense or labor. Rarely is the distribution of the plant the same in all pastures, and on many ranches some of the pastures are relatively free of the plant. With such favorable conditions at hand the lightly infested pastures should be lightly stocked until the blooming season, at which time the sheep and goats can all be held in this pasture until the blooms in the remainder of the pastures become woody and unpalatable. Lacking such favorable conditions a pasture may be selected which contains the least number of plants and a sufficient number of them grubbed out so that from the remainder it will be impossible for any particular animal to obtain sufficient of the blooms or buds to produce toxic effects. As the average length of the blooming season is about three weeks the length of time which will be required to hold the flock in one pasture is short and no serious results from overgrazing should follow such a short period. Burning of the plants has been recommended, but a single burning during the fall or winter months is not satisfactory as the burnt-off stump will produce the usual crop of blooms and the removal of the leaf of the plant has merely assisted the animals in harvesting the blooms. It is reasonable to assume that repeated burning should eventually kill the plant as the damage by fire is certainly as great if not greater than that resulting from constant grazing by cattle, which in many cases is exterminating the plant. From the standpoint of cattle feed the destruction of the plant is not a desirable practice since the leaves provide considerable grazing during the winter. Cutting or pulling the blooms and buds may be too laborious a task to be practical as a control measure.

DISCUSSION

It is to be noted that the basic or constant lesions of sacahuiste and lechuguilla poisoning are practically identical, but in the photodynamic aspect of the two diseases important differences are to be noted. In the case of lechuguilla poisoning the photosensitization was produced in animals when alfalfa hay was fed in addition to the plant; green grass was not required to produce this part of the disease. Lechuguilla was shown to contain two toxic principles (3). In the case of sacahuiste poisoning fresh green feed is required in order to render the animals sensitive to sunlight. It is

evident from these results that sacahuiste contains but one toxic principle, namely, a hepato-nephro-toxin. The complete clinical picture of sacahuiste poisoning is therefore similar to the condition produced by Quin (4) in which a photosensitization was produced in sheep and goats by feeding fresh green feed after ligation of the bile duct. The green feed in these experiments had no photodynamic action when fed to normal animals. In this strictly experimental condition the outstanding fact is the presence of photosensitization associated with an obstructive jaundice. Quin, Rimington, and Roets (5) showed that the photosensitization in these animals was due to the presence of phylloerythrin in the blood stream, a prophyrin produced in the digestive tract by infusorial action on chlorophyl, and which gains access to the blood stream by virtue of a liver disfunction. The toxic principle in sacahuiste produces a degeneration of the liver which results in an obstructive jaundice and a liver disfunction; in the absence of green feed this is the complete picture, but when green grass is added the animals become sensitive to sunlight. Since this part of the clinical picture was not obtained when the animals were fed dry alfalfa it is evident that the digestive action on dry and green chlorophyl is not the same.

No definite information concerning the chemical nature of the toxic principle in sacahuiste was obtained, but from the results obtained in animal feeding experiments on this phase of the problem, it is evident that it is not the same hepato-nephro-toxin which is found in lechuguilla. In the experimental feeding no great difference was noted in the toxicity of the two plants for either sheep or goats, and the toxic principle was found to withstand drying in both cases. The toxic saponin in lechuguilla was readily extracted with alcohol and one gram of the crude extract was found to be the minimum lethal dose for white rats. Furthermore, this toxic principle in the alcoholic extract was easily obtained in a more purified state and the purified product found to have much greater toxicity for rats. Although rats were killed by feeding the crude alcoholic extract of sacahuiste, the fatal results were due to purgation and not to a specific hepato-nephro-toxin such as was extracted from lechuguilla. In addition the methods employed in concentrating or purifying the toxic principle in extracts of lechuguilla were unsuccessful when applied to similar extracts of sacahuiste.

Due to the fact that the ripe fruit of the plant is small and exceedingly hard it was surprising that sheep could pick up from the ground sufficient of this material to produce toxic effects. It is hardly probable that this material will ever constitute a serious problem, but on one occasion a light loss was observed as a result of lambs eating the ripe fruit after it had shattered out of the dry bloom stock onto the ground.

SUMMARY

The grazing of buds and blooms of sacahuiste under range conditions has been observed to cause serious losses among sheep and goats, and to a lesser extent among cattle. The disease thus produced is described.

The feeding of the buds, blooms and ripe fruit to goats and sheep under experimental conditions produced the same disease manifestations as were observed on the ranges.

Icterus and liver and kidney destruction was produced when the toxic material was fed in conjunction with alfalfa hay. The addition of fresh green grass to the ration rendered the affected animals sensitive to sunlight.

The minimum toxic dose of the fresh buds and blooms for sheep was found to be about 1.1 per cent of the body weight.

The toxic principle which has a destructive action on the liver and kidneys could not be extracted with either ethyl or methyl alcohol.

The leaf of the plant is not considered to be toxic to cattle.

Methods for the control of sacahuiste poisoning are suggested.

LITERATURE CITED

1. Tunnicliff, E. A. 1929. Forty-second Annual Report, Texas Agricultural Experiment Station, page 139.
2. Mathews, F. P. 1937. Photosensitization and Photodynamic Diseases of Man and the Lower Animals. Archives of Pathology, 23, 339.
3. Mathews, F. P. 1937. Lechuguilla *(Agave lecheguilla)* Poisoning in Sheep, Goats and Laboratory Animals. Texas Agricultural Experiment Station Bulletin No. 554.
4. Quin, J. I. 1933. The Effect of Surgical Obstruction of the Normal Bile Flow. Onderstepoort Journal of Veterinary Science and Animal Industry, I, 505.
5. Quin, J. I., Rimington, C., and Roets, G. C. S. 1935. The Biological Formation of Phylloerythrin in the Digestive Tract of Various Domesticated Animals. Onderstepoort Journal of Veterinary Science and Animal Industry, 4, 463.